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ABSTRACT

Young children's responses to a velocity inference task based on static pictorial stimuli giving cues of proximity and ratio were examined. Subjects (N=65) in preschool through second grade viewed pictures of snails moving horizontally or spiders suspended vertically and were asked to estimate which competitor would reach its destination first. Cues on the diagrams included proximity of competitor to destination and distance already traveled. Easy diagrams had all other factors constant; difficult diagrams (including manipulated starting points and distances traveled) were solved correctly only if proper ratio calculations were made. Preliminary analylses showed no sex differences nor any effect of test order. Main effects of orientation (horizontal or vertical) and age-orientation interaction were not found, but a highly significant main effect of task difficulty (qualified by a significant age/task difficulty interaction) was revealed. Although older children develop strategies for velocity estimation, these skills do not result in correct judgments in all contexts. (DH)

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Developments in the Use of Proximity and Ratio Cues in Velocity Judgments

Beatrice Shire and Kevin Durkin

(Paper presented at the British Psychological Society, Developmental Section, Annual Conference, Lancaster University 1984)

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DEVELOPMENTS IN THE USE OF PROXIMITY AND RATIO CUES IN VELOCITY JUDGMENTS

Children's difficulties with problems involving ratio and proportion are familiar to teachers, and though analysis of error types (Hart, 1981. Karplus & Peterson, 1970) are informative, little work has investigated the development of understanding in this domain.

The experiment reported here is a first study of young children's responses to a velocity inference task, based on a static pictorial stimuli giving cues of proximity and ratio.

In the task, children were required to estimate which one of two competitors would reach a destination point first.

The competitors (snails and spiders), were presented pictorially: Fig. 1.

Insert Figure 1
about here

Two interacting cues are available in these diagrams:

(i) the relative proximity of each competitor to the destination;

(ii) the distance already travelled by each competitor - denoted by slimy trails for the snails and threads for the spiders.

Simply put, all other factors constant, one would expect the competitor nearer the destination to win as in Fig. 1a. Problems of this type were designated EASY and three essentially different diagrams fell into this category.

If the starting points and distances travelled are manipulated so that the competitor nearer the destination has travelled considerably less far than the other, as in Fig. 1b then a more complex calculation is required, taking into account the ratio of distances travelled to distances remaining, to establish that the competitor further from the destination would win. Problems of this type were designated DIFFICULT and three essentially different diagrams fell into this category.

The principal purpose of this experiment was to chart developments in the ability to make these ratio calculations, and to make use of the available cues.

PREDICTIONS

In the age range tested - Preschool and Infant classes - it was expected ratio calculation would be unlikely, and the main cue to be exploited would be proximity to the destination.

However, with children's understanding of proximity itself developing at this age, and preschoolers tending to equate proximity with contact (Durkin, 1984), it was predicted that the youngest children would perform randomly, while older children, exploiting the proximity cue, would respond correctly to the EASY items and consistently incorrectly to the DIFFICULT items.

SUBJECTS

Subjects were drawn from preschool and infant classes in villages in East Kent.

DISTRIBUTION OF SUBJECTS BY AGE

Age Group	N	Mean age in months	Age Range in months
Preschool	21 (14 M; 7 F)	45.4	31 - 59
1st Year	24 (12 M; 12F)	65.9	62 - 70
2nd Year	24 (11 M; 13 F)	90.7	81 - 101

MATERIALS

The diagrams were presented on plastic-covered card (A4 and ½ A4 sizes).

Each child saw 24 pictures: 12 of snails and 12 of spiders, involving the same distances in horizontal and vertical format.

Each of the six different diagrams was duplicated by reversing the relative positions of competitors, see Fig. 2.

Insert Fig.2 about here

Fig. 3 gives examples of each of the six different configurations of distances.

3 (i), (ii) and (iii) are the EASY items.

3 (iv), (v) and (vi) are the DIFFICULT items.

Insert Fig. 3 about here

PROCEDURE

Each child was tested individually, Snail and Spider tasks were given on different days, with the order of administration balanced, within each task the order of items was random.

The child sat opposite the experimenter with a low table between them on which the experimenter placed each card in turn, saying (for example):

"Here is a picture of two snails racing to a lettuce patch. You can see where the snails have been because they leave slimy trails. This snail started here, and this one started here; they are moving steadily towards the lettuce. The started at the same time, and

you can see where they have got to now; if they carry on the same way which one will get to the lettuce first?"

The child then pointed to the 'winner', and the experimenter noted on a separate sheet which one had been chosen. After the task the experimenter asked the child to explain his/her decisions.

RESULTS

The childrens responses were scored

1 for a correct answer.

0 for an incorrect answer.

and a total calculated for each child for EASY and DIFFICULT questions in each of the two formats HORIZONTAL and VERTICAL.

Preliminary analyses showed no sex-differences nor any effect of the test order.

Mean scores (out of 6) by age group for the four categories of questions are shown on Table 2 and Figure 4.

Figure 5 shows the scores for EASY and DIFFICULT items with HORIZONTAL and VERTICAL formats combined.

Insert figs. 4, 5 and Table 2
about here

Analysis of Variance (Age group (3) by Orientation (2) by Task Difficulty (2) showed no main effect of orientation nor any age/orientation interaction, but a highly significant main effect ($F(1,66) = 270.55$ $p<.001$) of task difficulty, which is qualified by a highly significant age/task difficulty interaction ($F(2,66) = 18.94$ $p<.001$).

As predicted, the older children achieved higher (near perfect) scores on the EASY items, and lower scores on the DIFFICULT items than did the youngest subjects. This demonstrates, after the age of about 5 years, a systematic use of the proximity cue, picking the competitor nearer the destination as the 'winner'. The schoolchildren's use of this cue was confirmed by their own explanations of their strategies.

If the children had answered randomly, the expected mean score in each category would be 3. The mean of preschool children's scores on DIFFICULT items did not differ significantly from this expected value:

$$Z \text{ (horizontal)} = 1.8 \quad (p > .07) \quad \text{N.S.}$$

$$Z \text{ (vertical)} = 0.19 \quad (p > .85) \quad \text{N.S.}$$

though they scored significantly better than chance on the EASY items.

Fig.6. Shows mean scores for each test item by age group, and illustrates the consistency of responses within EASY/ DIFFICULT categories, except for test item (iv). The improved score on this item alone accounts for the increase in "DIFFICULT" scores between 1st and 2nd year schoolchildren.

In test item (iv) the competitors are equidistant from the destination, making calculations involving speed much simpler, and the use of a proximity cue less likely. (see Fig. 7)

Insert Figs. 6, 7
about here

DISCUSSION

The experiment has confirmed that children develop strategies to cope with the demands of velocity estimation during the years 3 to 8, though the most common strategies do not result in correct judgments in all contexts, even in our older subjects.

Judgments based on proximity cues appear to start around the age when previous research (Durkin, 1980, 1984) has indicated

that 'nearness' ceases to mean 'in contact with'. Explanations of their responses elicited from the subjects in post-test discussions support this interpretation. The preschool children mentioned neither proximity nor speed but gave imprecise comparisons based on task-irrelevant dimensions or answers which were seemingly idiosyncratic; for example:

That one will win because "that one's bigger"
"they're the same size"
"spiders have long legs"
"I just know"
"he does"
"he'll eat the other one up"

Children in other age groups mentioned relevant featrues such as the length of the trail (or thread) and proximity, for example:

That one will win because "he's nearest"
"he's nearly there"
"he started nearer"
"he's a bit closer"
"it's a longer trail"
"he's lower"

In other work (Shire, Durkin and Crowther, forthcoming), we have found that acquisition of the use of the proximity term near in mathematical context is also developing during this age range and beyond. It appears that as children's grasp of the everyday meaning of the preposition develops so they are increasingly likely to attend to or, if called upon, use the word in educational contexts.

However, spatial terminology actually serves to convey specialised meaning in many educational contexts, and these are not always congruent with everyday uses (Durkin, Crowther, Shire, Riem and Nash, forthcoming).

Hence, children experience problems with this area of educational vocabulary for some years (Durkin, et al forthcoming). The present study shows that, consistent with our assumption of protracted development in this sphere, readiness to exploit proximity as a cue in some cognitive tasks develops quite late.

Several older children mentioned speed as a factor in their calculations. Although they did not achieve correct scores on all of the DIFFICULT items, the age-related improvement on item (iv) scores suggests that, in optimal conditions, the

ability to make ratio calculations is emerging during this period. That this is earlier than children would normally be expected to tackle such calculations numerically is consistent with Hart's findings (Hart, 1981) that children are generally more successful with problems presented diagramatically or as word problems than with the same problems presented as "Straightforward" calculations.

Extensions of the present design are planned including older subjects exploiting non-static media, and manipulating the presence or relational terminology, to vary the quality of the cues available.

Such work will help ascertain at which age ratio calculations become prevalent and which cues facilitate or impede such judgments. Disentangling the relationship of linguistic and contextual factors in mathematical estimations has important practical implications for school work in this area, and theoretical implications for the study of the role of relational language in perceptual development.

TABLE 2

MEAN CORRECT SCORES BY AGE-GROUP

(s.d.s. in parentheses)

Age Group	HORIZONTAL (Snails)		VERTICAL (Spiders)	
	Easy	Difficult	Easy	Difficult
Preschool	4.43 (1.66)	2.52 (2.09)	4.43 (1.75)	2.95 (1.99)
First Year	5.93 (0.48)	0.96 (1.63)	6.00 (0.00)	1.33 (1.99)
Second Year	6.00 (0.00)	1.33 (1.66)	5.92 (0.41)	1.46 (2.02)

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Fig. 1 a.

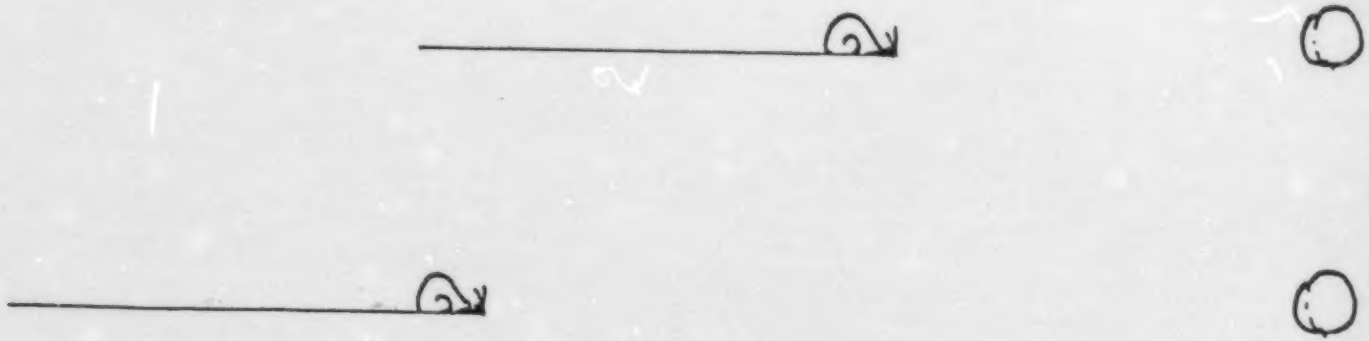


Fig. 1 b.

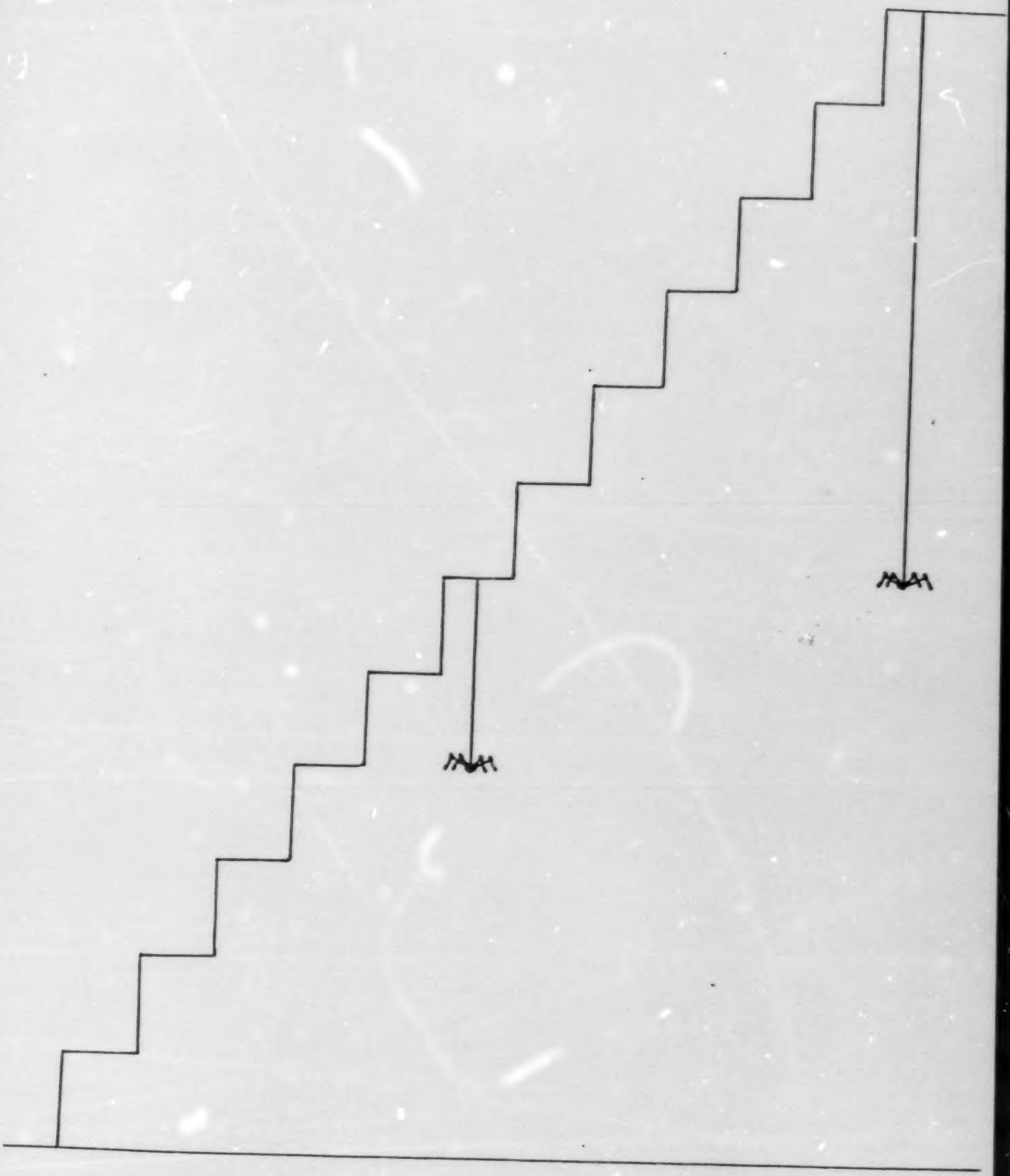


Fig 2 a.

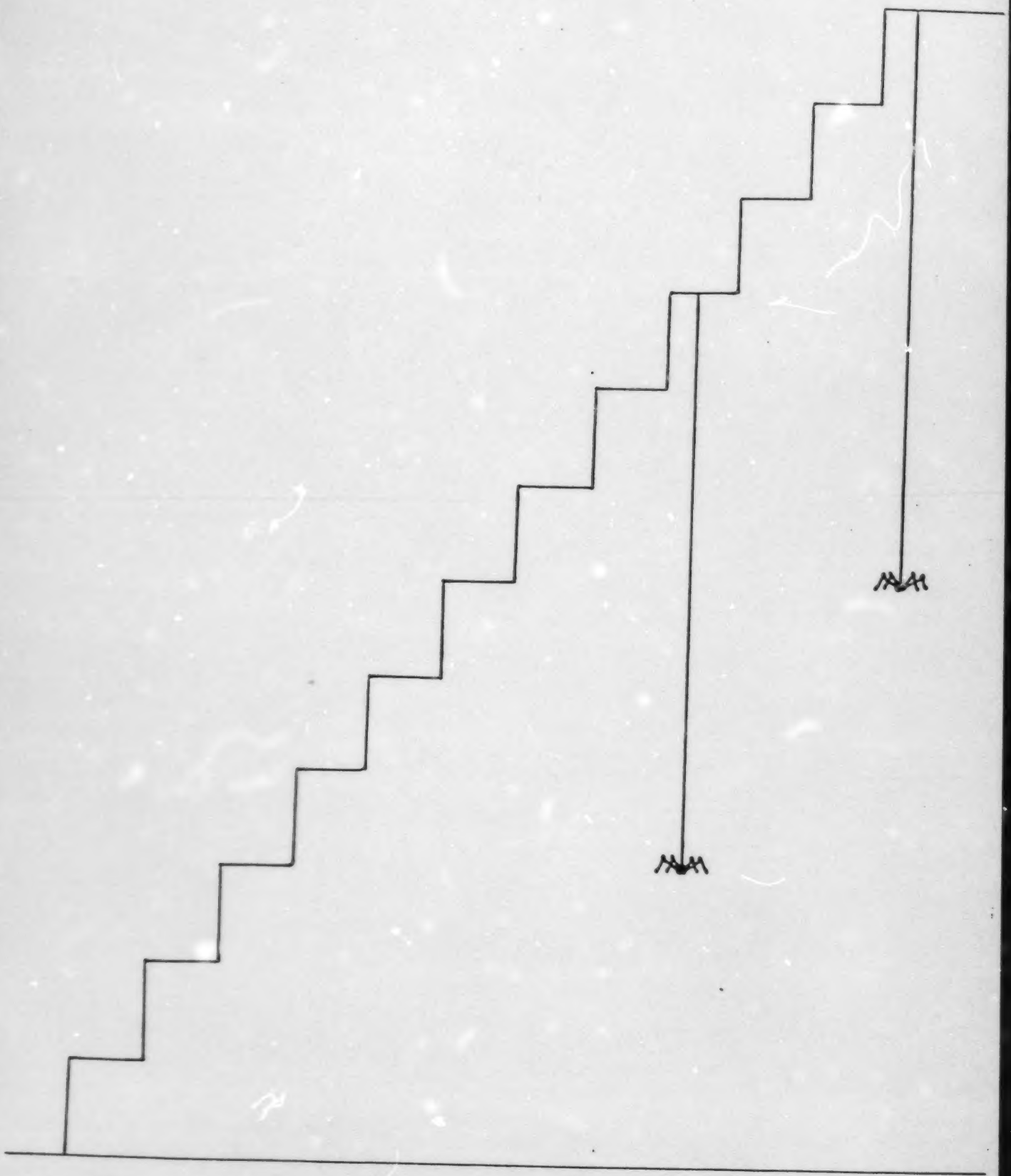
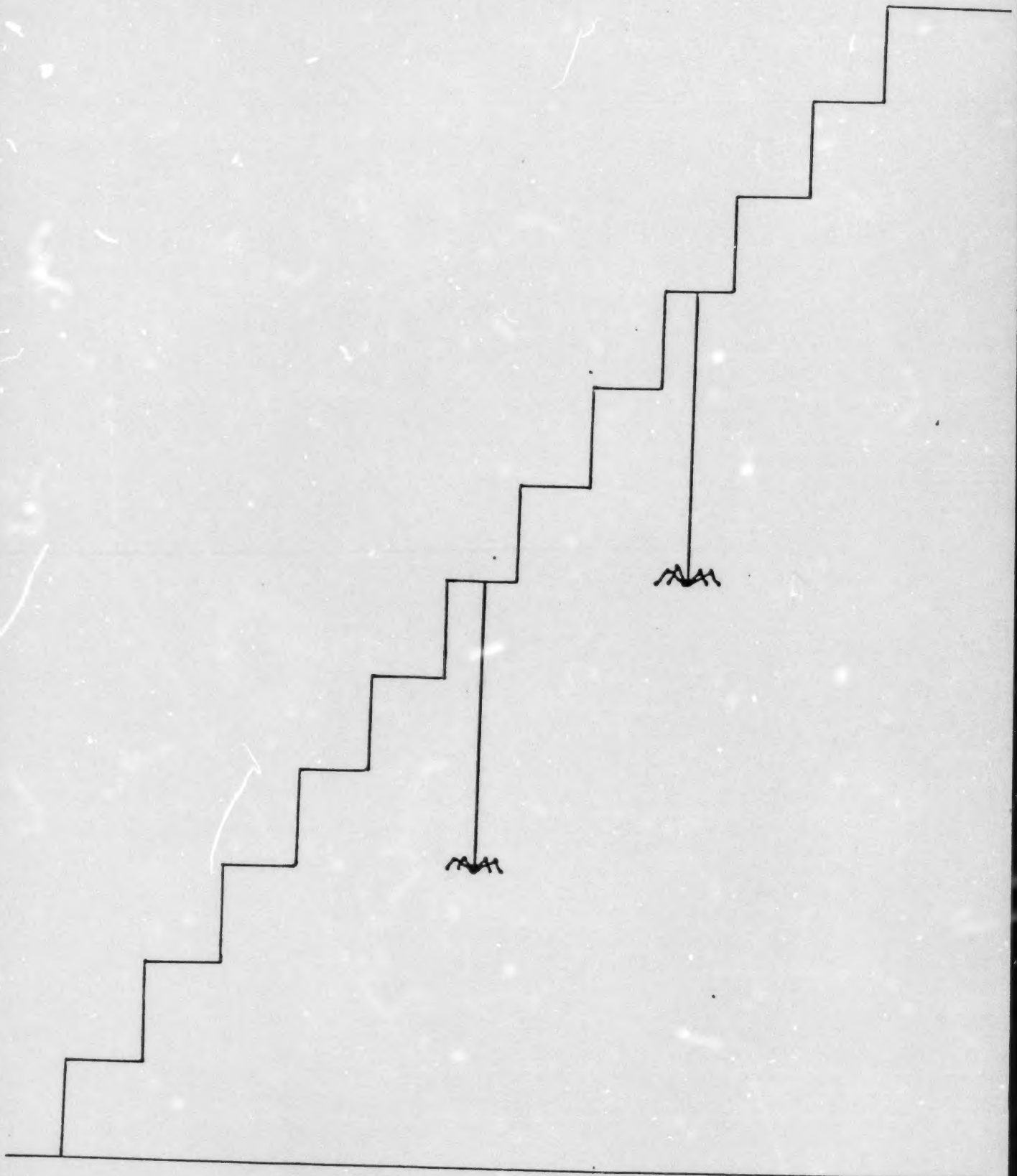
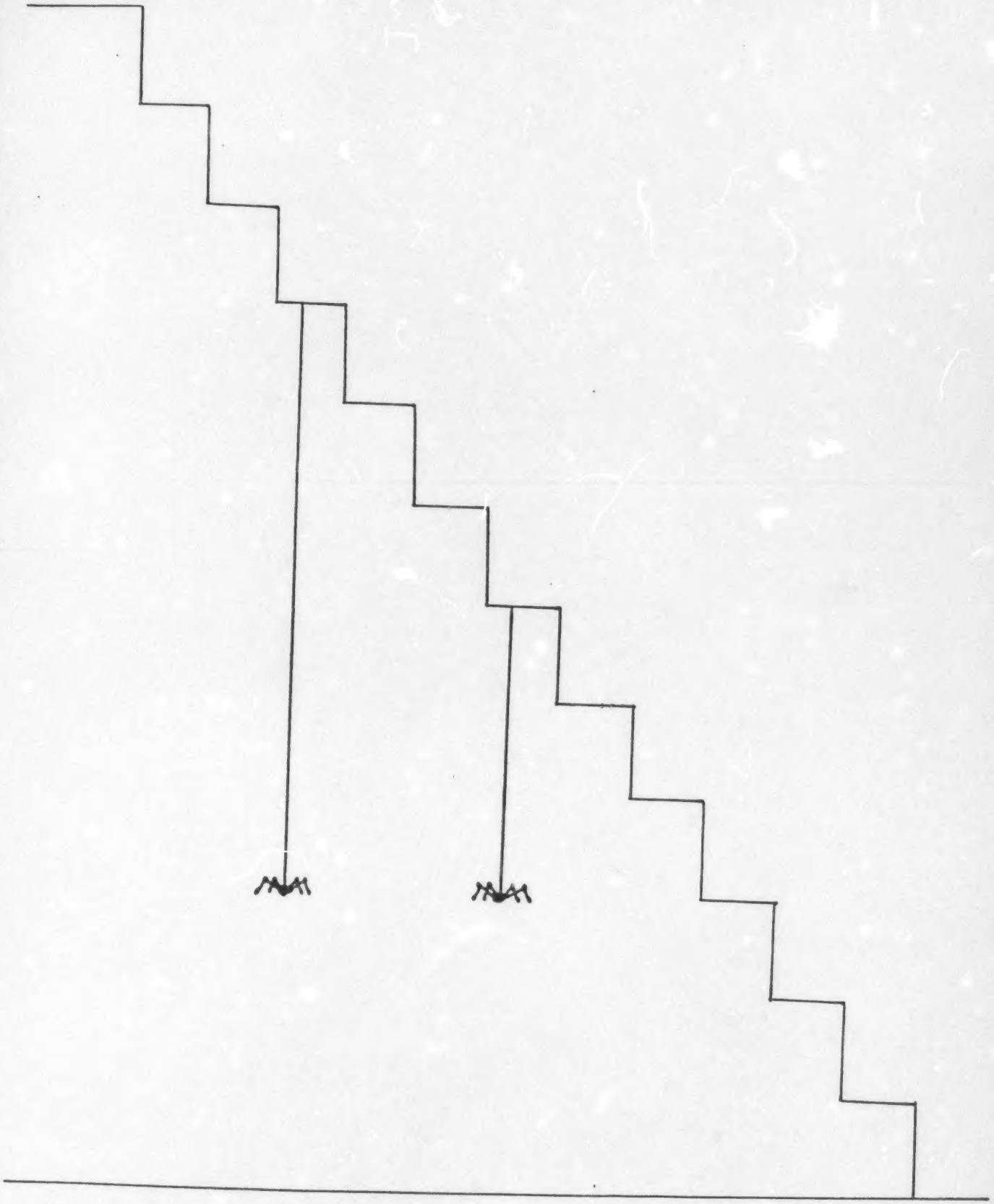


Fig. 2 b.

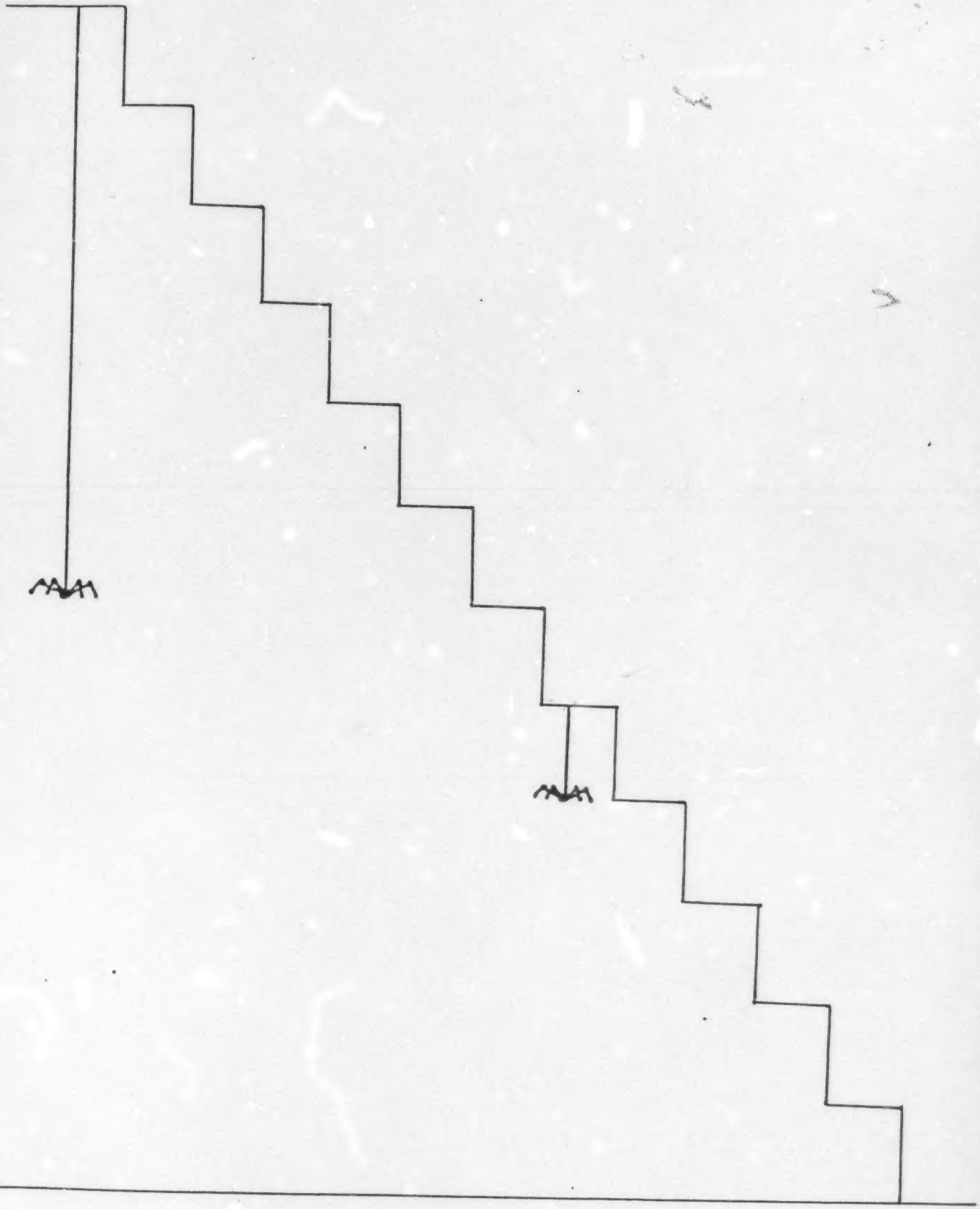
3 (1)



3 (iv)



3 (vi)



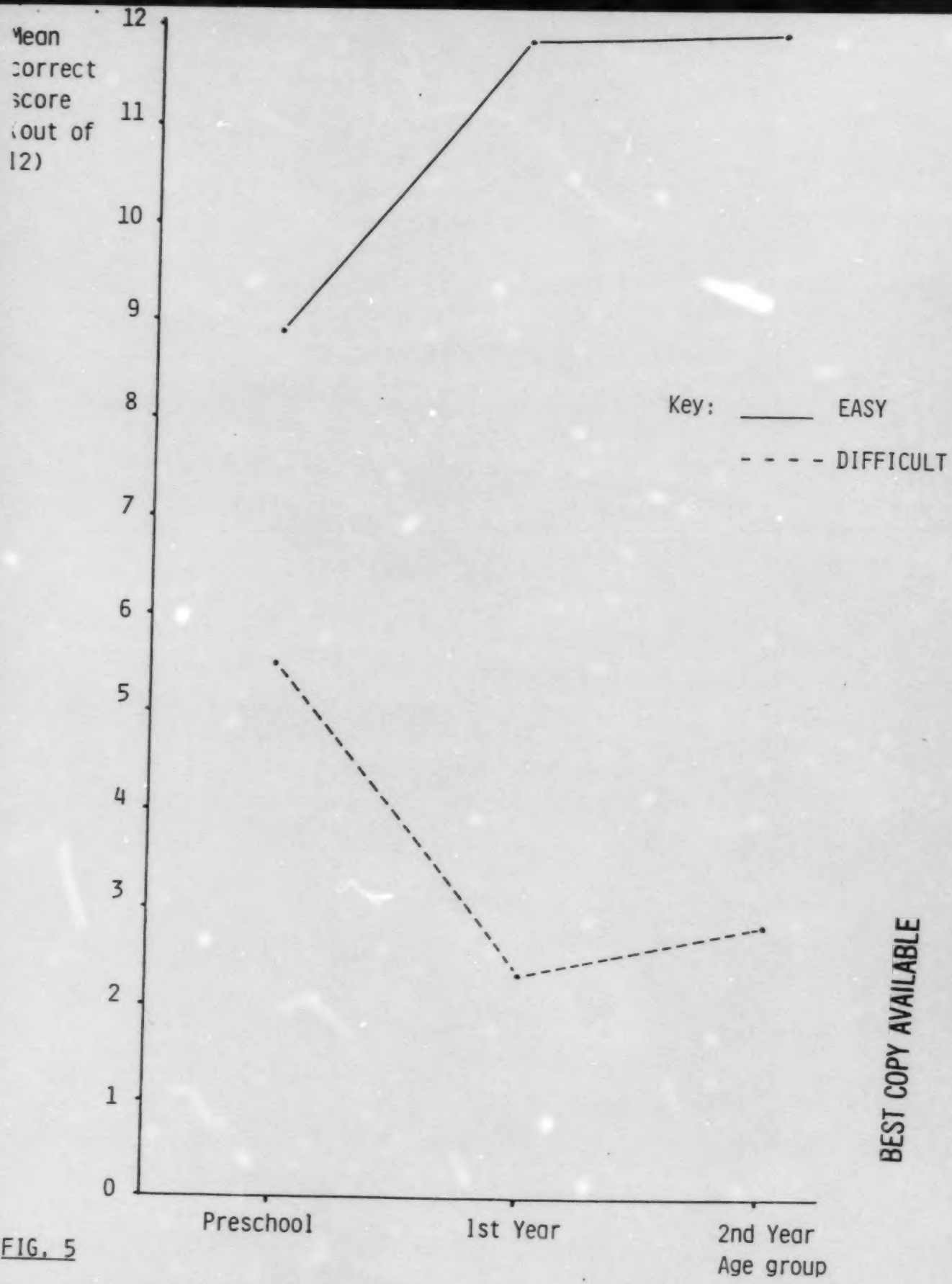


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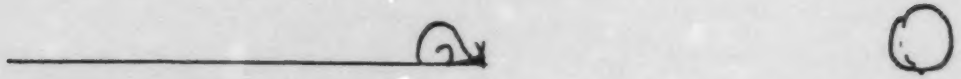
FIG. 5

Mean Correct Score (out of 12) for EASY and DIFFICULT items by age group



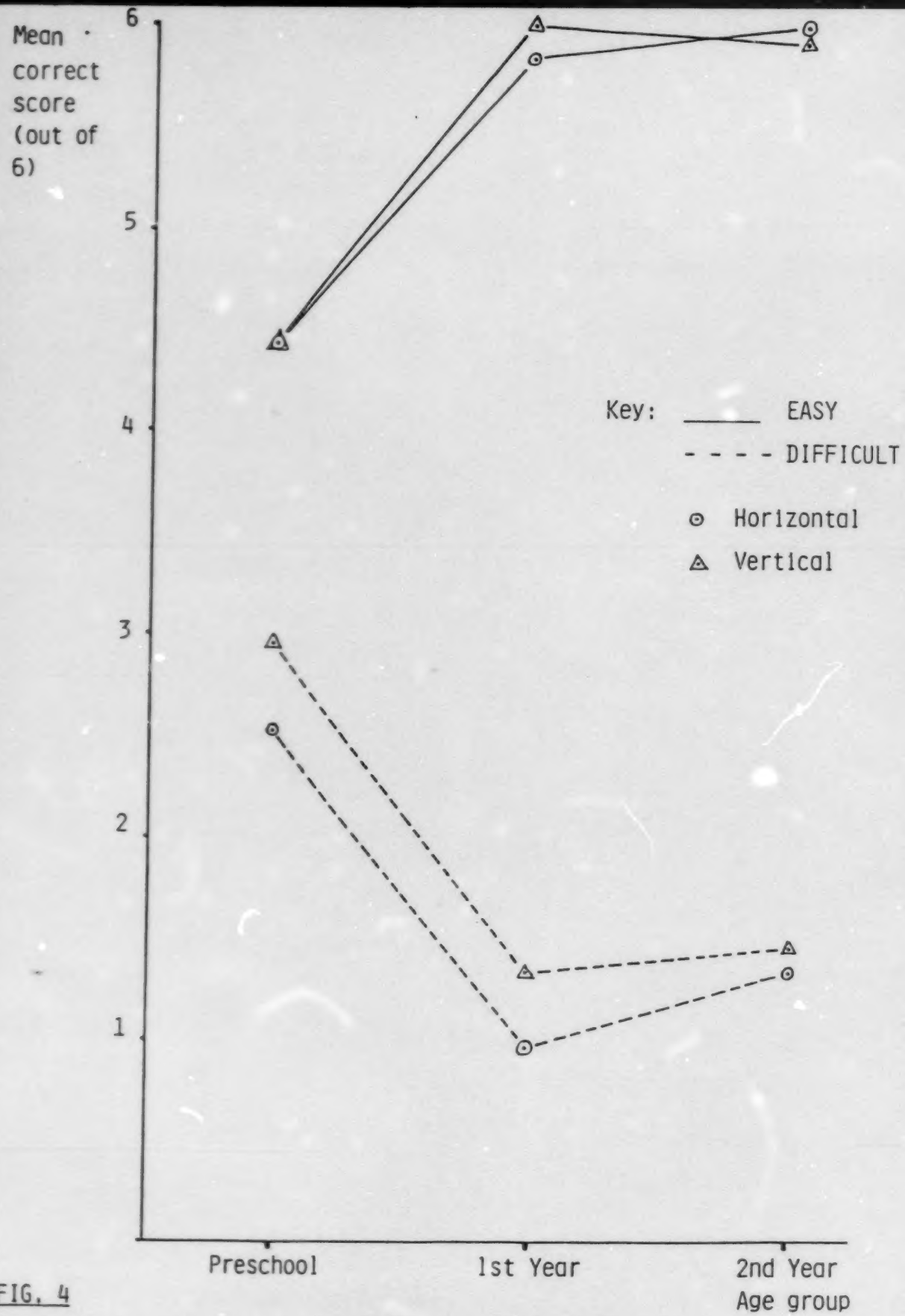


FIG. 4

MEAN CORRECT SCORES (out of 6) for EASY and DIFFICULT Items by orientation and age group

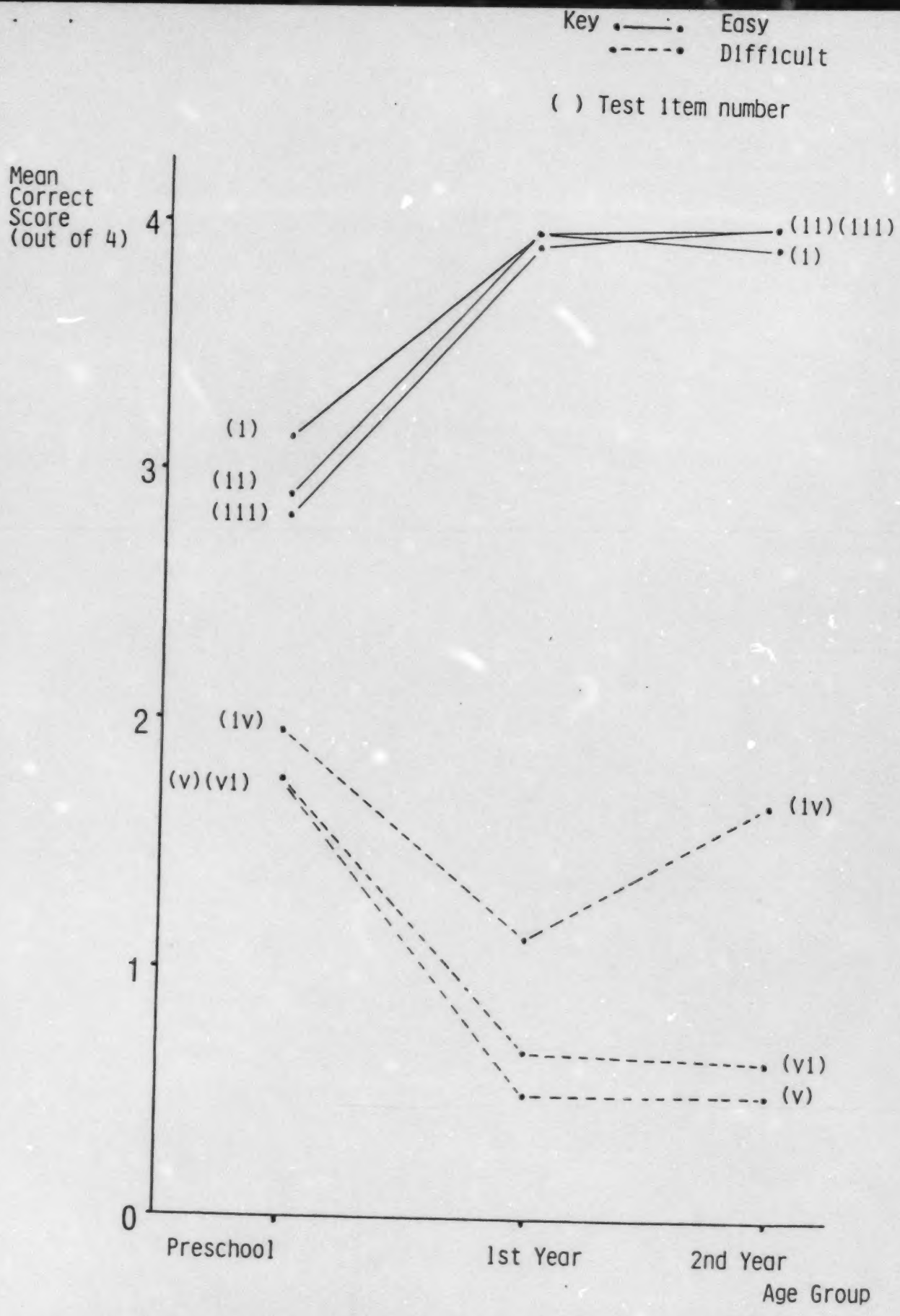


Fig. 6. Mean Correct Scores (out of 4) for each test item by Age Group